Concentration Ratios of Radiocesium from Soil to Wild Boar Observed in Fukushima Prefecture – 14151

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ABSTRACT

After the Fukushima Daiichi Nuclear Power Plant accident, soil surfaces were contaminated with radiocesium. Although the non-uniform contamination was found in Fukushima Prefecture, the radiocesium concentration in wild boar meat can be estimated if the concentration ratios from soil to the animal are obtained. In this study, therefore, reported radiocesium concentration data from food monitoring and soil samples collected in the prefecture were used to estimate the concentration ratios. The ratio was defined as the wild boar meat concentration (Bq/kg-fresh mass) divided by the area concentration (Bq/m^2), thus the area base concentration ratio, that is, CR_{agg} was calculated. The wild boar meat data sampled between 551 to 734 days after March 11, 2011 were used, and soil concentrations were selected in the areas corresponding to the areas where meat sample had been obtained. The geometric mean value of the data was used for CR_{agg} calculation. In all, 189 CR_{agg} data were calculated, and the geometric mean value was 8.8×10^{-3} (range: 3.3×10^{-4} to 8.4×10^{-1}). Radiocesium concentration in wild boar meat could be roughly estimated using the summarized data.

INTRODUCTION

Soon after the Great East Japan Earthquake on March 11, 2011, four units at TEPCO's Fukushima Daiichi Nuclear Power Plant (FDNPP) site were severely damaged by huge tsunami. Due to the large release of radionuclides from the FDNPP, agricultural products were heavily contaminated in some areas in northeastern Japan in the following 2-3 months. Since then, radiocesium concentrations in most agricultural products and drinking water have been lower than the detection limit. However, the radioactivity in some game animals, e.g., wild boar and bear, caught in Fukushima Prefecture and surrounding areas some times showed higher values than the standard limit of 100 Bq/kg-fresh even about 30 months after the accident [1].

Previously, we reported the radiocesium concentration change in meat of wild animals with time using the data from food monitoring results collected in mainly prefectures in northeastern Japan. The concentration tended to decrease with time; however, we also found that prediction of the concentration for individual animals would be difficult because some would migrate from contaminated areas or would eat highly contaminated food like mushrooms [2]. Indeed, during the mushroom growing season (late summer to early autumn in 2012), the radiocesium concentration in wild boar meat tended to increase. Nonetheless, the concentrations in soil and wild boar meat should have some useful correlations.

To understand the radionuclide effect on animals and their protection from radiation exposure under equilibrium conditions (during nuclear power plant operation and the long-term dose effect after radioactive waste disposal), concentration ratios (CRs) from media to animals and plants were proposed by ICRP [3]. However, the situation after the FDNPP accident is different; only thin soil surface layer contamination has been found, and the distribution on the surface soil is not uniform. Thus, it is difficult to apply the CRs to the Fukushima situation. In this study, therefore the aggregated concentration ratio (CR_{agg}) of radiocesium from soil (Bq/m^2) to wild

boar (Bq/kg-fresh) was proposed and the values were calculated to get information on potential wild boar contamination levels in Fukushima Prefecture provided soil concentration data in the unit Bq/m^2 are available.

MATERIALS AND METHODS

To eliminate the physiological decay factor of Cs-134, data for Cs-137 were used in this study. The wild boar data were from food monitoring results expressed in Bq/kg-fresh [1]. For the boar meat samples collected between 551 to 734 days after March 11, 2011, corresponding soil sample collection areas in Fukushima were identified [4]. Each soil collection area was about 25.8 km^2 (5.6 km × 4.6 km) in size. There were also soil concentration data (Bq/m^2) available from the study results of the Ministry of Education, Culture, Sports, Science and Technology, Japan [5]. One collection area usually had a several soil concentration data, however, if there were no data for the corresponding area, the data observed in the next grids were applied. If more than three soil data were available in one grid, then, the geometric mean was calculated. Finally, Cs-137 concentrations in wild boar meat and corresponding area were compiled in one work sheet. Then, the area base concentration ratio, CR_{agg} was calculated using the following equation.

CR_{agg} (m^2/kg) = wild boar meat concentration (Bq/kg-fresh mass) / area concentration (Bq/m^2)

RESULTS AND DISCUSSION

Probability distributions of Cs-137 concentrations in 189 wild boar meat samples and in 59 corresponding area soil samples (geometric mean values) are plotted in Fig. 1. For each sample, all the data showed a log-normal distribution, therefore, geometric mean values were calculated for wild boar and soil samples, and the values were 653 Bq/kg-fresh and 64.8 kBq/m^2, respectively.

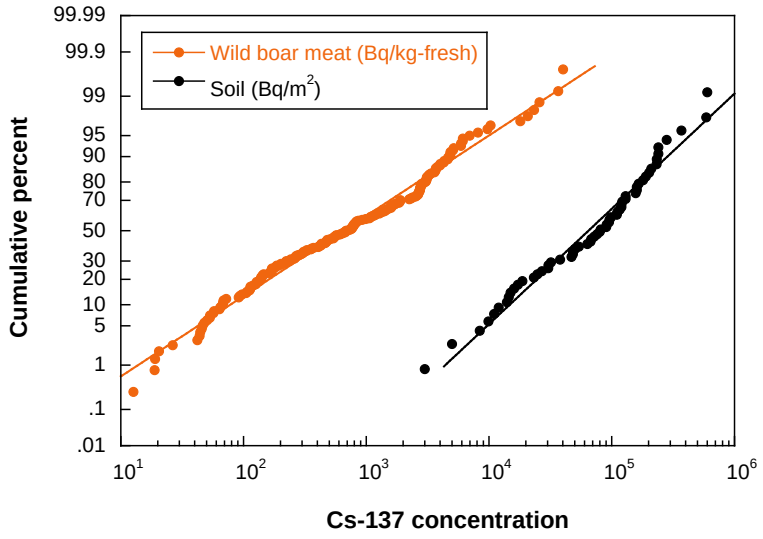

Fig. 1. Probability distributions of Cs-137 concentrations in wild boar meat and soil samples collected in Fukushima Prefecture.

Using these data sets, we calculated CR_{agg} values and the determined geometric mean value for all the samples was 8.8×10^{-3} with wide variations from 3.3×10^{-4} to 8.4×10^{-1}. Hence, we could

roughly estimate radiocesium concentration in wild boar meat using the data. However, it would be useful if the factors causing the wide range of CR_{agg} were clarified. Table I shows the geometric mean values of the CR_{agg} for the sampling areas having more than three data. The geometric mean values of CR_{agg} ranged from 1.7×10^{-3} to 1.0×10^{-1}. When these data are plotted against distance from the coast to the sampling area as shown in Fig. 2, some correlations were implied between them; indeed, the correlation factor between distance and $\log(CR_{agg})$ was -0.69 with $p<0.001$ by t-test. Since coastal areas contain higher sea salt concentrations than inland areas the mobility of radiocesium in the former might be higher than that in the latter. However, further study is needed to understand the sea salt effect on radiocesium mobility near the coastal areas.

TABLE I. Concentration ratio (CR_{agg}) of radiocesium from soil to wild boar for samples collected in Fukushima Prefecture 551 to 734 days after March 11, 2011.

Collection area	Number of data	Distance from the coastal line to the area center point (km)	CR_{agg}		
			Geometric mean	Min	Max
A	3	102	1.7E-03	1.3E-03	1.9E-03
B	4	23	5.7E-03	2.3E-03	1.4E-02
C	4	18	2.4E-03	9.9E-04	4.2E-03
D	4	18	4.8E-03	4.5E-03	5.2E-03
E	3	67	4.8E-03	3.4E-03	6.9E-03
F	7	50	4.2E-03	3.3E-04	1.0E-02
G	4	50	4.5E-03	2.4E-03	6.6E-03
H	3	44	7.3E-03	2.0E-03	1.5E-02
I	3	44	8.6E-03	6.2E-03	1.6E-02
J	3	34	1.8E-03	6.5E-04	5.2E-03
K	30	33	3.5E-03	8.4E-04	1.2E-02
L	4	11	2.1E-02	8.5E-03	6.1E-02
M	13	6	1.9E-02	1.5E-02	3.6E-02
N	3	60	4.8E-03	4.0E-03	6.4E-03
O	3	11	1.0E-01	8.3E-02	1.4E-01
P	4	1	6.3E-02	3.6E-02	1.7E-01
Q	18	4	3.9E-02	1.1E-02	8.0E-02
R	7	48	7.0E-03	4.0E-03	1.3E-02
S	9	4	1.7E-02	8.9E-03	4.6E-02
T	9	6	3.1E-02	2.0E-02	4.0E-02
All	189	-	8.8E-03	3.3E-04	8.4E-01

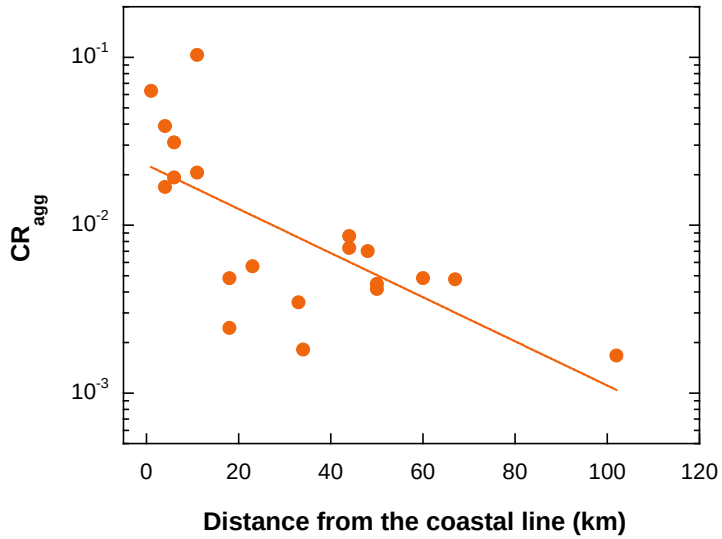

Fig. 2. Correlation between CR_{agg} and distance from the coastal line to the sampling area center point (km).

The present data are difficult to compare with the data published in ICRP Pub. 114 [3] because of the different definition and species. Regarding the definition, the concentration ratio used in ICRP Pub. 114 is based on Bq/kg-fresh mass of biota and Bq/kg-dry soil, however, in the literature [3], mass base concentration was not available. In order to convert the present data it is necessary to convert the soil area concentration data (Bq/m^2) to the mass concentration (Bq/kg-dry). In our previous paper, we converted soil data in Bq/kg to Bq/m^2 using the conversion factor of 52.5 [6]; we applied this value to the present study. Thus, Bq/m^2 data were divided by the conversion factor, and then, the CR was calculated. The geometric mean value was 4.6×10^{-1} with a range of 1.8×10^{-2} to 4.4×10^{1}. To compare the data, we selected CR data from reference mammals listed in ICRP Pub. 114; the values for rat and deer were 2.2×10^{-1} and 1.6×10^{0}, respecitlvey. Thus, the value observed in this study fell within this range. The radiocesium distribution in soil is not uniform to a certain depth in Fukushima Prefecture, and thus it was expected that the CR values of wild boar meat in the prefecture would be different fro those form reference mammals obtained under equilibrium conditions. However, possibly due to the low mobility of the radionuclide in the soil environment, non-uniform radiocesium vertical distribution in soil might not have caused the difference in CR levels for terrestrial mammals.

CONCLUSIONS

We obtained area concentration ratio from soil to wild boar meat samples (CR_{agg}) to estimate radiocesium concentration in wild boar meat. The ratio was proposed because the radiocesium distributions in the surface soil environment and the soil vertical distribution have not been uniform in short term since the accident. To obtain the CR_{agg} values, Cs-137 concentration data available online were used for both wild boar meat and soil. Wild boar sample collection areas were clearly known for 189 samples collected between 551 to 734 days after March 11, 2011. Thus corresponding soil data were selected and then CR_{agg} values were obtained. Interestingly, when these CR_{agg} data were plotted against distance from the coast to the sampling area center point, a good correlation was observed. The results implied sea salt might affect the radiocesium mobility in coastal areas; however, more study is necessary to clarify the effect. The geometric

mean of all the CR_{agg} values obtained was 8.8×10^{-3}. The CR_{agg} data should be useful to estimate the radiation effect to wild boar and the ecosystems.

REFERENCES

[1] Ministry of Health, Labour and Welfare, Japan. “Monthly Report of Test results of radionuclide in foods sampled since 01 April 2012,” available at http://www.mhlw.go.jp/english/topics/2011eq/index_food_radioactive.html, accessed November 2, 2013.
[2] K. TAGAMI and S. UCHIDA, “Radiocesium Concentration Change in Game Animals: Use of Food Monitoring Data, “ Proceedings of WM2013, Phoenix, Feb. 24-28, ISBN 978-0-9836186-2-1, No. 13168, p.9 (2013).
[3] ICRP Environmental Protection: Transfer Parameters for Reference Animals and Plants, pp. 17-53, C.H. CLEMENT Ed., ICRP Publication 114, Ann. ICRP 39(6) (2009).
[4] Fukushima Prefecture, “Concentrations of Radiocesium in Game Animals,” available at http://wwwcms.pref.fukushima.jp/pcp_portal/PortalServlet;jsessionid=5557128F1DC64A7DBDE2695750E8600E?DISPLAY_ID=DIRECT&NEXT_DISPLAY_ID=U000004&CONTENTS_ID=26118, Accessed November 2, 2013.
[5] Ministry of Education, Culture, Sports, Science and Technology, “Extension Site of Distribution Map of Radiation Dose, etc.,” available at http://ramap.jmc.or.jp/map/eng/, accessed November 2, 2013.
[6] K. TAGAMI, S. UCHIDA, N. ISHII and J. ZHENG, “Estimation of Te-132 Distribution in Fukushima Prefecture at the Early Stage of the Fukushima Daiichi Nuclear Power Plant Reactor Failures,” Environ. Sci. Technol. 47, 5007-5012 (2013).

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